Takashi MIKAWA: **A taxonomic study on Japanese sporangiferous Mucorales** (2)**

三川 隆*: 日本産胞子嚢性ケカビ目菌類の分類学的研究 (2)**

Cunninghamellaceae Naumov ex Benjamin, Aliso 4: 415 (1959)

Sporangiophores arising from substrate mycelia, aerial mycelia or on stolons opposite the rhizoids. Sporangia and sporangiola always absent. Monosporous sporangiola borne on denticles of head vesicles, decidious. Zygospores globose to subglobose. Suspensors H-like.

Type genus: *Cunninghamella* Matruchot.

Naumov (1935) separated *Cunninghamella*, *Sigmoidiomyces* and *Thamnocephalis* from the Choanephoraceae on the basis of the presence of "conidia" and erected the Cunninghamellaceae. In addition to these genera, *Mycotypha* was added to this family by Hesseltine (1955). This family has been defined by the following features: 1) absence of both sporangia and sporangiola, 2) the occurrence of "conidia" borne on head vesicles, 3) the presence of zygospores with H-like suspensors (Naumov, 1939; Cutter, 1946; Hesseltine, 1955; Hesseltine & Ellis, 1973).

Traditionally the occurrence of "conidia" has been overestimated as a taxonomic criterion of the Cunninghamellaceae. "Conidia" of this family cannot be superficially distinguished from monosporous sporangiola at optical microscope level. Recently, however, it was demonstrated that "conidia" of *Cunninghamella* and *Mycotypha* were one-spored sporangia (Young, 1969; Khan & Talbot, 1975). From this evidence, Benny & Benjamin (1975) transferred *Mycotypha* to the Thamnidiaceae, and pointed out that the presence of monosporous sporangiola should not be employed as a taxonomic criterion at the family level.

In the members of the Cunninghamellaceae, the occurrence of head vesicles is regular throughout the culture. It is also noticed that the genera which have head vesicles are capable of producing monosporous sporangiola

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* Institute of Biological Sciences, The University of Tsukuba, Sakura-mura, Ibaraki-ken, Japan.
筑波大学生物科学系.

** Continued from Journ. Jap. Bot. **53**: 361-368, (1978).

or sporangiola. Therefore, the presence of the head vesicles can be used as reliable taxonomic character for separating this family from others. From this fact, I took up the presence of head vesicles, monosporous sporangiola and zygospores with H-like suspensors as the taxonomic criteria of the Cunninghamellaceae. Therefore, *Mycotypha* is included in this family in the present study.

Four genera have been added to this family, in which the following two genera have been found in Japan.

Key to genera of the Cunninghamellaceae

1. Head vesicles cylindrical .... *Mycotypha*
1. Head vesicles globose to obovoid, not cylindrical .... *Cunninghamella*

Cunninghamella Matruchot, Ann. Mycol. **1**: 47 (1903).

Actinocephalum Saito, Bot. Mag. Tokyo **19**: 36 (1905)—*Saitomyces* Ricker, J. Mycol. **12**: 61 (1906)—*Muratella* Bainier et Sartory, Bull. Soc. Mycol. Fr. **29**: 129 (1913).

Rhizoids and stolons present. Sporangiophores arising singly or in cluster from substrate mycelia, aerial mycelia or on stolons opposite the rhizoids, usually non septate, rarely becoming septate in age, branched. Head vesicles globose to obovid, rarely obpyriform. Zygospores verrucose. Suspensors without appendages.

Type species: *Cunninghamella africana* Matruchot

Seven species have been hitherto known, in which the following three species have been found in Japan.

Key to species

1. Fungi homothallic .... *C. homothallica*
1. Fungi heterothallic...2
2. Colonies powdery in appearance, dull yellow orange in color. Monosporous sporangia echinulate, with spines of up to 3.2 μm long.... *C. echinulata*
2. Colonies floccose in appearance, light brownish gray in color. Monosporous sporangiola smooth or echinulate, with spines of up to 1.0 μm long.. .... *C. elegans*

1) **Cunninghamella echinulata** (Thaxter) Thaxter, Rhodora **5**: 98 (1903).

Oedocephalum echinulatum Thaxter, Bot. Gaz. **16**: 17 (1891)—*Cunning-*

hamella africana Matruchot, Ann. Mycol. **1**: 47 (1903)—*Actinocephalum japonicum* Saito, Bot. Mag. Tokyo **19**: 36 (1905)—*Saitomyces japonicus* (Saito) Ricker, J. Mycol. **12**: 61 (1906)—*Muratella elegans* Bainier et Sartory, Bull. Soc. Mycol. Fr. **29**: 129 (1913)—*Cunninghamella dalmatica* Pispek, Acta Bot. Inst. Bot., Zagreb. **4**: 101 (1929)—*C. ramosa* Pispek, Acta Bot. Inst. Bot., Zagreb. **4**: 102 (1929)—*C. candida* Yamamoto, J. Agr. Chem. Soc. Japan **5**: 286 (1929)—*C. japonica* (Saito) Ito, Mycol. Fl. Japan **1**: 304 (1936)—*C. bainieri* Naumov, Clés des Mucorinées 107 (1939).

Illust.: Matsushima, T. 1975., Pl. 415, figs. 1, 2; Otani, Y. & T. Kojiro 1950., Pl. 1, figs. 3; Saito, K. 1905., Pl. II, figs. 1-12; Yamamoto, Y. 1929. figs. G; figs. 2, a-c.

Colonies on LCA incubated at 20°C for a week dull yellow orange, 3-5 mm high. Vegetative hyphae hyaline, up to 16.8 μm wide. Gemmae not observed. Sporangiophores hyaline, 7.7-16. 2 μm wide, verticillately or pseudoverticillately branched in the apical portion; main sporangiophores and their branches ending into head vesicles. Head vesicles globose to obovoid, 22.3-53.8 μm in diam., smooth or echinulate. Monosporous sporangiola globose, ovoid or ellipsoid, 9.7-29×9.4-28 μm, hyaline to light brown or dark yellowish brown, echinulate, with spines of up to 3.2 μm long. Zygospores not observed.

Hab. and Loc. coll.: from forest soil, Nippara, Tokyo (Mikawa-no. 711); garden soil, Otsuka, Tokyo (Mikawa-no. 913): rat dung, Mitsune, Hachijo Isl. (Mikawa-no. 498); rat dung, Usuki, Oita Pref. (Mikawa-no. 261); air, Kumagaya, Saitama Pref. [Ito, S. 1936 as *C. japonica* (Saito) Ito]; cultivated soil, Kyoto city, Kyoto (Matsushima, T. 1975); garden soil, Tottori University, Tottori Pref. (Otani, Y. & T. Kojiro, 1950); air, Kumagaya, Saitama Pref. (Saito, K. 1905 as *Actinocephalum japonicum* Saito); soil, Hokkaido, (Yamamoto, Y. 1929 as *C. candida* Yamamoto).

Zygospores have been found by many authors, including Cutter (1946) and Samson (1969).

Among the present isolates, no. 913 produces giant conidia in abundance on special vesicles, and was identified as *C. bainieri*. According to Ling-Young (1935) and Cutter (1946), giant condia are formed on special lateral vesicles or interspersed with normal monosporous sporangiola on both head and lateral vesicles, and they are said to be distinguished from normal monosporous sporangiola by its shape, size and color. Some isolates such as no.

498 and 711 have a tendency to produce giant conidia on older culture plate, and these two isolates can be identified as *C. bainieri* or *C. echinulata*. At present, I followed Samson's view (1969), and identified these isolates as *C. echinulata*. In no. 261, no giant conidia was observed even in older culture plate. This isolate agreed with the original description of *C. echinulata* and the description given by Otani & Kojiro (1950) and Matsushima (1975).

C. echinulata has been distinguished from *C. bainieri* by the branching type of sporangiophores, lack of giant conidia and the difference of maximum temperature (growth at 40°C in *C. echinulata*, whereas no growth at 40°C in *C. bainieri*). Samson (1969) treated *C. bainieri* as a synonym of *C. echinulata* based on the mating experiment of two species and growth of *C. bainieri* at 40°C. He characterized *C. echinulata* by the powdery appearance of colony, irregular, verticillately branched sporangiophores and the presence of giant conidia. However, he noted that giant conidia not always present.

Saito (1905) described a monotypic genus *Actinocephalum*, based on *A. japonicum*. Fitzpatrick (1930) pointed out that this genus was identical with *Cunninghamella*. Then, Ito (1936) presented a new combination, *Cunninghamella joponica* (Saito) Ito. Recently, Samson (1969) pointed out that *A. japonicum* was closely related to *C. echinulata* and he treated it as a synonym of *C. echinulata*. On the other hand, *A. japonicum* has been treated as a synonym of *C. elegans* (Zycha, 1935; Naumov, 1939; Zycha *et al*., 1969). If *A. japonicum* is identical with *C. elegans*, then *C. japonica* (Saito) Ito must be maintained in preferance to *C. elegans* on the basis of priority. Judging from the size range of monosporous sporangiola, *A. japonicum* can be distinguished from *C. elegans*, but agreed with *C. echinulata* (Fig. 1). In addition, judging from the original description and illustration of *A. japonicum*, this species seems to be a synonym of *C. echinulata*.

In 1929, Yamamoto described a new species, *C. candida*. According to him, *C. candida* is distinguished from *C. elegans* by the following features: 1) terminal and lateral vesicles of C. *candida* are 20-100 μm long and 8-20 μm wide, while these of C. *elegans* are up to 60 μm long and 18-20μm wide, respectively, 2) "conidia" of C. *candida* are 10-15×13-18 μm, while these of C. *elegans* are 8-14×8-16 μm. Ito (1936) retained it as a separate species. As shown in Fig. 1, *C. candida* can be distinguished from the present isolates of *C. elegans*, but agreed with the present isolates of *C. echinulata*. In addi-

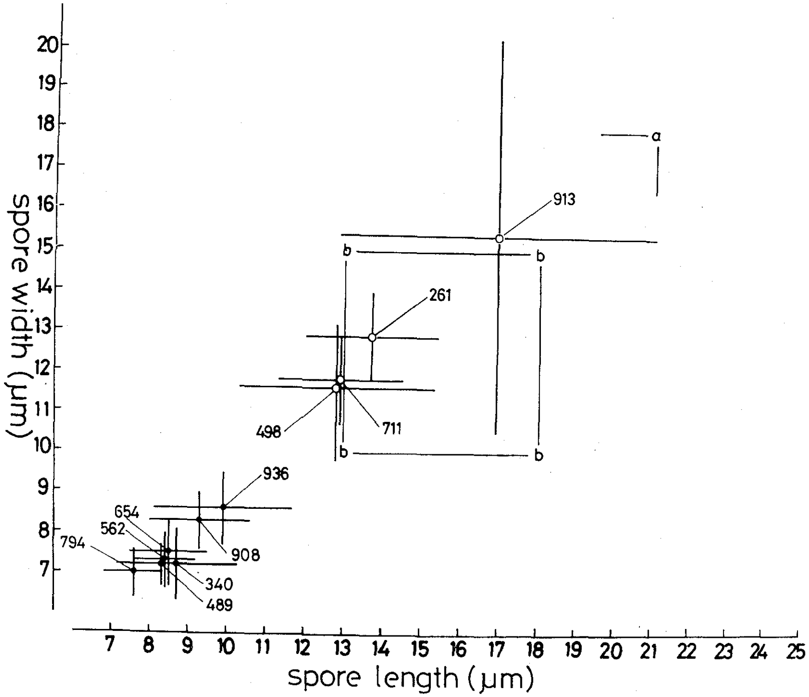


Fig. 1. Standard deviations for spore length and spore width. Arabic figures indicate isolates of *Cunninghamella*. The measurments based on 50 spores per isolate. ●: *C. elegans*. ○: *C. echinulata*. a: Saito (1905). b: Yamamoto (1929).

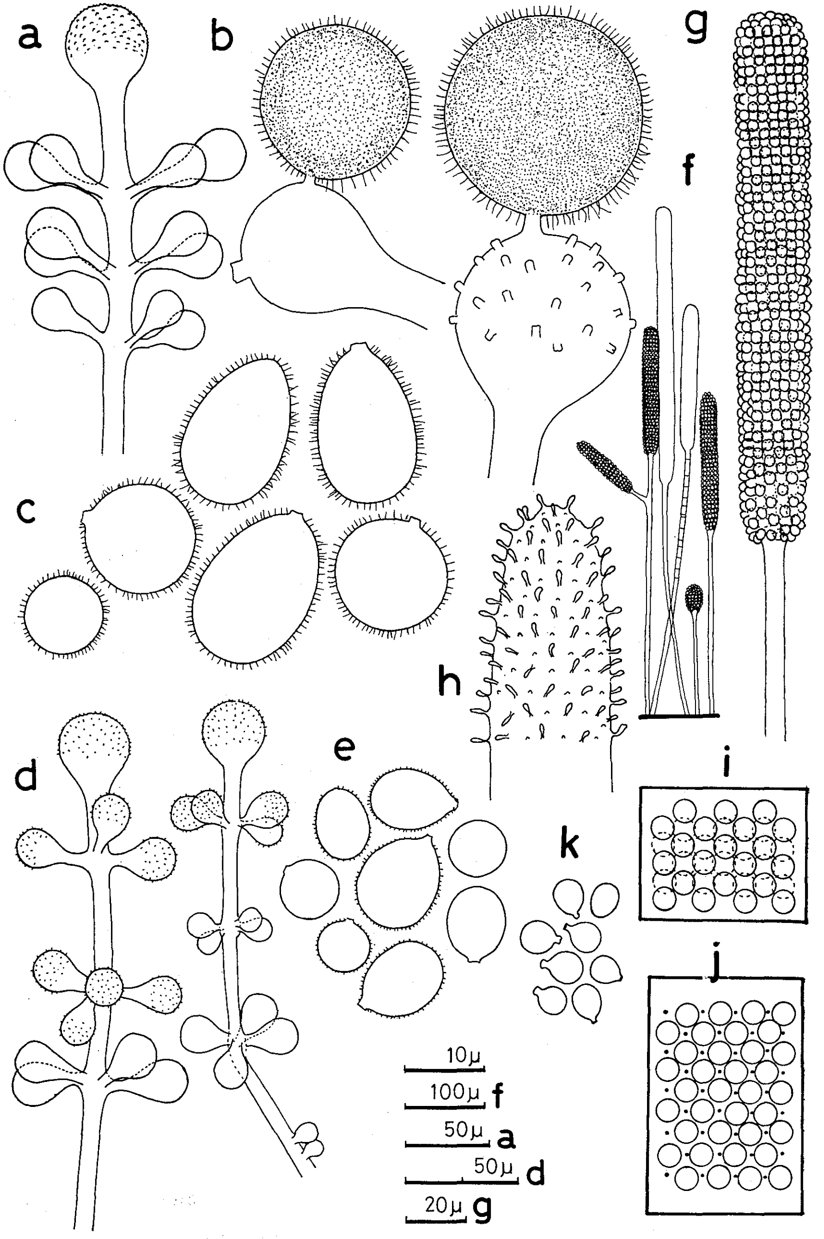
tion, judging from the original description and illustration on the colony color, verticillately branched sporangiophores and echinulate "conidia", *C. candida* probably should be reduced to a synonym of *C. echinulata*.

2) **Cunninghamella elegans** Lendner, Bull. Herb. Boissier 7: 250 (1907).

Cunninghamella bertholletiae Stadel, Diss. Kiel. 1-35 (1911).

Illust.: Otani, Y. & T. Kojiro. 1950. Pl. 1, fig. 2; Yamamoto, Y. 1929. fig. F; figs. 2, d, e.

Colonies on LCA incubated at 20°C for a week light brownish gray, 1.5 cm high. Vegetative hyphae hyaline, up to 15.4 μm wide. Gemmae not observed. Sporangiophores hyaline, 7.7-14.6 μm wide, verticillately branched in the apical portion of sporangiophres; main sporangiophores and their branches ending into head vesicles. Head vesicles globose to obovoid, 10.8-41.5 μm in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diam., smooth or echinulate. Monosporous sporangiola globose or ovoid, 6.3-14.1×6.3-10.3 μm, hyaline to pale yellowish brown, smooth or echinulate with short spines of up to 1.0 μm long. Zygospores not observed.

Hab. and Loc. coll.: from forest soil, Nopporo, Hokkaido (Mikawa-no. 564) ; forest soil, Hachinohe, Aomori Pref. (Mikawa-no. 562) ; cultivated soil, Ashigakubo, Saitama Pref. (Mikawa-no. 908) ; forest soil, Mitsune, Hachijo Isl. (Mikawa-no. 479) ; forest soil, Mt. Hachijo-Fuji, Hachijo Isl. (Mikawa-no. 489) ; forest soil, Niimi, Okayama Pref. (Mikawa-no. 746) ; forest soil, Izumotaisha, Shimane Pref. (Mikawa-no. 743) ; forest soil, Tsuwano, Shimane Pref. (Mikawa-no. 794) ; cultivated soil kindly collected by Dr. Koichiro Miura in Shitogo, Yaku Isl. (Mikawa-no. 654) ; forest soil kindly collected by Sueo Kato in Chichijima, Bonin Isl. (Mikawa-no. 936) ; leaf litter kindly collected by Dr. Koichiro Miura in Arakawa, Ishigaki Isl. (Mikawa-no. 340) ; soil, Hokkaido (Ito, S. 1936) ; larch forest soil, Sugadaira, Nagano Pref. (Lee, Ji-Yul. 1972) ; cultivated soil, Okayama city, Okayama Pref. (Matsushima, T. 1975) ; soil, Tottori Pref. (Otani, Y. & T. Kojiro. 1950) ; cultivated soil, Hokkaido (Yamamoto, Y. 1929).

Zygospores have been found by many authors, including Cutter (1946) and Samson (1969).

The present isolates agreed with the original description and the description given by Samson (1969), Otani & Kojiro (1950) and Lee (1972).

C. elegans was distinguished from *C. echinulata* by the following features: 1) colony color of *C. elegans* is light brownish gray, while that of *C. echinulata* is dull yellow orange, 2) monosporous sporangiola of *C. elegans* are mostly 7.5-9.9×7.2-8.6 μm in size, whereas these of *C. echinulata* are mostly 13-17×11.6-15.4 μm in size, 3) monosporous sporangiola in *C. elegans* are smooth or echinulate with spines of up to 1.0 μm long, while those of *C. echinulata* are echinulate with spines of up to 3.2 μm long.

Figs. 2. a-c. *Cunninghamella echinulata*. a. Sporangiophore bearing head vesicles. b. Giant conidia borne on special vesicles. c. Monosporous sporangiola. d, e. *Cunninghamella. elegans*. d. Sporangiophores bearing head vesicles. e. Monosporous sporangiola. f-k. *Mycotypha microspora*. f. Habit sketch of sporangiophores. g. Head vesicle covered with monosporous sporangiola. h. Early stage in monosporous sporangiola formation. i. Diagramatic illustration, showing an arrangement of monosporous sporangiola; solid line shows spores attached to "long" denticles and dotted line indicates spores attached to "short" denticles. j. Diagramatic illustration, showing an arrangement of denticles; dots show "long" denticles of spores and a circle indicates spores attached to "short" denticles. k. Monosporous sporangiola.

As described previously, Zycha (1935) treated *Actinocephalum japonicum* as a synonym of *C. elegans*. Some mycologists including Naumov (1939) and Zycha *et al.* (1969) agreed that *A. japonicum* was a synonym of *C. elegans*. If so, *Cunninghamella japonica* (Saito) Ito must be a valid species since it antedates *C. elegans*.

3) **Cunninghamella homothallica** Kominami et Tubaki, Nagaoa 1: 21 (1952).

Illust.: Kominami, K. & K. Tubaki. 1952. fig. 15.

Hab. and Loc. coll.: from soil, Nature Study, National Sciences Museum, Meguro, Tokyo (Kominami, K. & K. Tubaki. 1952).

No additional record of this species has been known since the original description.

Mycotypha Fenner, Mycologia 24: 196 (1932).

Rhizoids and stolons absent. Sporangiophores arising singly from substrate mycelia, usually unbranched, rarely branched, at first non septate, later adventitiously septate. Head vesicles cylindrical. Zygospores verrucose. Suspensors without appendages.

Type species: *Mycotypha microspora* Fenner

Two species have been hitherto known, in which only one species has been found in Japan.

Mycotypha microspora Fenner, Mycologia 24: 196 (1932).

Illust.: Mikawa, T. 1975. figs. 1, A-D; figs. 2, f-k.

Colonies on LCA incubated at 20°C for ten days light olive gray to dark yellowish brown, 5 mm high. Vegetative hyphae hyaline, up to 25.8 μm wide. Gemmae not observed. Sporangiophores at first hyaline, later becoming brownish, 5-12.5 μm wide, unbranched, rarely branched monopodially. Head vesicles (33.3-) 350-690.6 μm long, 12.5-23.3 μm wide, echinulate. Monosporous sporangiola subglobose to ovoid, 2.2-3.8 × 3.0-4.4 μm, hyaline, smooth, apiculate. Zygospores not observed.

Hab. and Loc. coll.: from rat dung, Usuki, Oita Pref. (Mikawa, T. 1975).

Fenner (1932) observed helical arrangement of the monosporous sporangiola on the head vesicles and noted that denticles of one coil alternated with those on the coil above and below it. The arrangement of denticles was also demonstrated by Young (1969). According to him, *M. microspora* has two types of denticles, "long" and "short". Two types of denticles alternate on the vesicles, and arrange in a transverse helix or diagonal row.

Whereas, Khan & Talbot (1975) found that monosporous sporangiola on "short" denticles arrange in a line with the minor axis and those on "long" denticles arrange in a line with the major axis.

When I have reported this species in 1975, I payed no attention to the arrangement of denticles. At present, therefore, I confirmed the above character in the present isolate and illustrated it. As pointed out by Young (1969), the alternation of "short" and "long" denticles was also observed in the present isolate. The transverse helix or diagonal rows could be traced. "Long" and "short" denticles also appear to be arranged in a line with the minor axis (Figs. 2, h-j).

References

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Cunninghamellaceae に所属する2属4種を報告した。*Actinocephalum japonicum* Saito と *Cunninghamella candida* Yamamoto は，両種共に *C. echinulata* と *C.*

elegans に類似しているため，従来，これらの菌群の種の階級の分類は論議の焦点とされてきた。今回，これらの二種を再検討した結果，両種共に *C. echinulata* の異名同種として取扱うことが妥当であると結論した。

□湖北省植物研究所編著：**湖北植物誌** vol. 1, pp. 508, 1976, ¥1,900. 中国でも各省単位でフロラがではじめたようだが，とくに湖北省は日本の温帯と関連が深く，さらに第一巻はドクダミ科からクスノキ科に及ぶ系統的に古い群と裸子植物とから成るから，まことに興味深いものがある。各科各属毎に纏めてあり，それにつづいて各種を述べているが，ほぼ種毎に図を添えてあるのでわかり易い。全体としてみると，我が国の属はほとんど顔を出し，しかも種数がより多いのは，面積の広さもあろうし，フロラの豊富さもきいていよう。*Quercus*, *Polygonum* などは大きくとっているが，サバノオ属は *Dichocarpum*, ミズヒキ属は独立して *Antenoron* を使っている。葉脚が円くてはっきりしているコウライイタドリ *Reynoutria henryi* Nakai はイタドリの異名になっているのは腑に落ちないが，大勢としてはほぼ妥当であろう。続きがでるのが待遠しいといえよう。（前川文夫）

□Robert T. Clausen 著 **Sedum of North America North of the Mexican Plateau.** 742 pp. Cornell University Press, Ithaca. 1975年。24000円。Clausen 教授の北アメリカのマンネングサ属に関する2番目の大著である。即ち *Sedum* of the Trans-Mexican Volcanic Belt (1959年) がそれで，本書は前書がカバーした地域より北方に自生，野化，栽培する種類を，前書とほぼ同じ方法で解説したモノグラフといえる。北アメリカのマンネングサ属については，North American Flora 22巻に Britton と Rose (1905年) が，一応既知の種類をまとめて以来の著作であり，北アメリカの同属植物を知るうえで大いに参考となる。数量形質については，前書と同様な統計処理が用いられている。60図におよぶ線画と，102葉の生体写真は，いずれも鮮明なものである。分布図は22葉が収められている。従来マンネングサ属の節とされることの多かったイワベンケイ類，ベンケイソウ類を亜属とする等，幾つかの新見解も発表されている。数量形質の計測を含め，記載は詳細ではあるが，子房の形態（特に基部の状態，腹側の突起の有無），花序の分岐の仕方，開花時の花弁の開出度，裂開直前の葯の色などいくつかの形質の記載がないのは，それらが種によって一定したものだけに惜しまれる。（大場秀章）